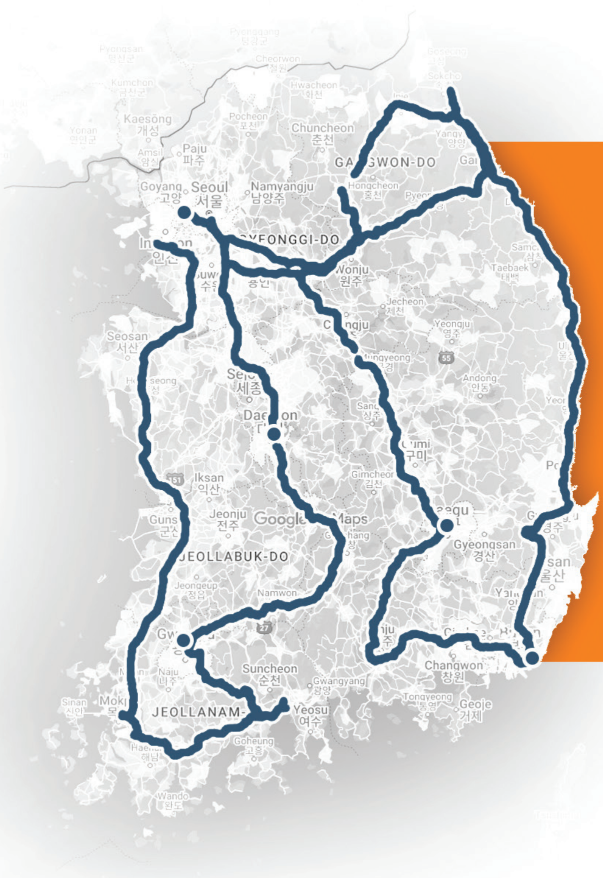
PRECISE POSITIONING
Korea Drive Test

Abstract

Precise positioning is a critical enabler of autonomy, navigation, tracking, and mapping in industries such as automotive, robotics, fleet management, construction, and utilities. Swift Navigation, with global operations spanning North America, Europe, Asia, and Australia, delivers precise GNSS corrections via its Skylark™ Precise Positioning Service. In South Korea, Swift provides nationwide coverage in close collaboration with Korea Telecom (KT), supporting the deployment of advanced autonomous systems and location-based technologies at scale.

In February 2025, Swift and KT conducted an extensive drive test to demonstrate Skylark's accuracy and reliability under real-world conditions. The 2,526 km test route included expressways, national roads, urban canyons, tunnels, and rural areas, comparing uncorrected GNSS against Skylark-corrected results. The test leveraged the Teseo V GNSS receiver from Swift's partner STMicroelectronics, which is optimized for ADAS, L2+, and autonomous driving.



The results confirm Skylark's ability to significantly improve positioning accuracy, achieving:

21x BETTER RESULTS

than uncorrected GNSS across the entire test.

Precise Positioning for Automotive

Transforming Mobility with Precise Positioning

Advancements in connected and autonomous vehicle technology are reshaping the automotive industry, driving safer, more efficient mobility solutions. Today's vehicles are equipped with precise navigation, real-time maps, Advanced Driver Assistance Systems (ADAS) and Vehicle-to-Everything (V2X) communication, and continue to advance to greater levels of autonomy.

To enable these capabilities, vehicles require a robust positioning system that integrates multiple sensors, including radar, cameras, LiDAR, inertial sensors, and GNSS. Traditional driver assistance systems have primarily relied on perception-based sensors but GNSS is now taking on a larger role to expand operating environments and enhance safety and reliability. Perception sensors, such as LiDAR and cameras, can enable incredibly precise localization in feature-rich areas with detailed HD maps such as city centers, but they have shortcomings as well. Because they rely on "seeing" physical features, they do not perform well in poor weather conditions and environments with limited visibility.

GNSS, on the other hand, excels where perception-based sensors struggle, such as in feature-sparse environments like unmarked roads or in low-visibility weather conditions. Furthermore, GNSS does not lose precision at higher velocities whereas the accuracy of perception based localization systems degrades at highway speeds and GNSS is also uncorrelated with perception sensors, adding an extra layer of redundancy to enhance the reliability and availability of autonomous systems.

Key Requirements for Modern Automotive Positioning

To support advanced autonomous functions, precise GNSS positioning solutions must meet stringent automotive industry demands:

- **Reliable Accuracy:** Achieving lane-level precision, rapid convergence, and seamless availability across vast geographic regions.
- **Guaranteed Safety:** Compliance with ASIL (Automotive Safety Integrity Level) standards for functional safety, ensuring that positioning solutions meet rigorous trust and performance requirements.
- **System Interoperability:** Compatibility with diverse automotive-grade GNSS receivers, sensor stacks, and compute platforms to ensure seamless integration.

Skylark meets and exceeds these requirements, delivering ASIL-certified absolute positioning as part of an end-to-end positioning solution with advanced sensor fusion or as an interoperable component of any automotive tech stack. Designed from the ground up to enhance ADAS, autonomy, and V2X applications, Skylark is the first and only cloud-based positioning service to achieve ISO 26262 certification. Unlike other GNSS corrections services, which are hosted in physical data centers, Skylark's cloud architecture enables mass market scale at an affordable price point.

Overcoming Key Challenges in Autonomous Vehicle Development

Automotive OEMs and Tier 1 suppliers face three critical challenges when developing autonomous systems for their vehicles: high system and sensor costs, limited scalability, and complex integration with existing hardware and software. Skylark addresses these challenges by providing a solution that reduces costs, scales seamlessly, and integrates effortlessly into existing automotive ecosystems.

Challenge 1: High System Costs

Developing autonomous systems typically requires expensive sensor suites, high-performance compute, and extensive HD map infrastructure. Skylark mitigates these costs by:

- **Eliminating the need for expensive physical data centers with its cloud-native service.** Unlike traditional solutions that rely heavily on on-premise infrastructure, Skylark ensures high-integrity GNSS corrections via the cloud, reducing overhead and maintenance costs.

- **Minimizing dependence on high-cost Simultaneous Localization and Mapping (SLAM) sensors** through Skylark's cloud-based processing. Many current solutions require high-density LiDAR arrays and expensive compute power to process sensor fusion in real time, whereas Skylark's positioning algorithms have lower bandwidth and lighter computational loads.

- **Lowering the cost of HD map creation and maintenance by leveraging cloud-based corrections.** Traditional HD map creation requires frequent updates and extensive in-person data collection, driving up operational expenses. Skylark enables dynamic map updates with accurate, real-time positioning data, reducing the need for expensive map refresh cycles.

Challenge 2: Limited Scalability

Scalability is a key concern as autonomous solutions progress from Level 0 (basic driver assistance) to Level 5 (full automation). Skylark enables seamless scalability through:

- **A cloud-based architecture that delivers high-integrity, safety-certified positioning for all autonomy levels.** Unlike on-premise solutions limited by local server infrastructure, Skylark leverages secure, redundant AWS infrastructure to reduce reliance on physical servers and flexibly scale to meet capacity as needed.

- **Global service availability.** Many GNSS-based positioning solutions are limited by their reliance on a dense physical base station network. Skylark overcomes this by using a proprietary atmospheric model that delivers higher accuracy with sparse infrastructure, enabling consistent accuracy across continents.

Challenge 3: Complex Integrations

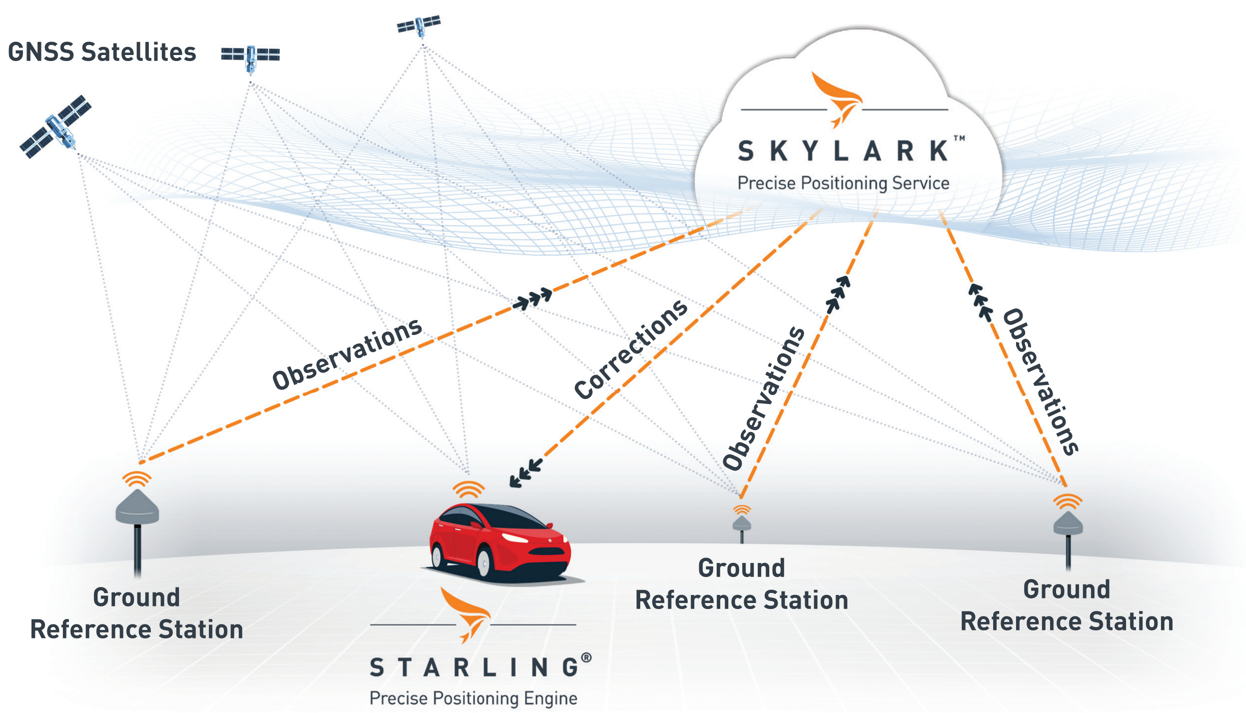
Integrating new positioning solutions with existing automotive ecosystems can be complex and costly. Skylark simplifies this process by offering:

- **A software-based solution that is sensor-, hardware-, and OS-agnostic, reducing integration overhead and accelerating development cycles.** Traditional positioning solutions often require proprietary hardware or closed software ecosystems, creating challenges for OEMs looking to integrate across multiple platforms. Swift's solution seamlessly integrates into existing vehicle architectures and accelerates integration timelines.

- **Future-proof technology designed to evolve with industry advancements and regulatory requirements.** The automotive industry is rapidly evolving, with increasing regulatory oversight on localization technologies. Skylark ensures compliance with evolving industry standards while maintaining flexibility to support new sensors and software architectures.

Swift Navigation Precise Positioning

Designed to meet the strict requirements of automotive deployments, Swift's Automotive Suite delivers a complete software solution for precise vehicle localization.



Swift's Automotive Suite includes:

- **Skylark Precise Positioning Service:** A real-time, cloud-based PPP-RTK correction service that delivers highly accurate, highly reliable, positioning across large-scale regions.

  Skylark comes with an Integrity option that enables functional safety compliance by delivering trusted positioning data with quantifiable confidence levels. This option is built on a robust integrity framework that continuously monitors for feared events—such as satellite faults, atmospheric anomalies, and station outages—and flags suspect measurements in real time. Designed to support ASIL-rated systems, it ensures that safety-critical applications have highly trustworthy location data and timely alerts when confidence falls below defined thresholds.

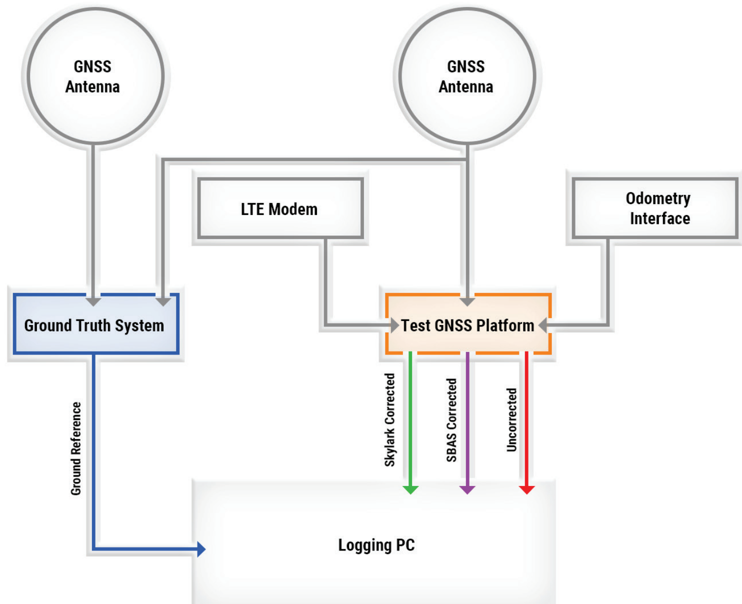
- **Starling Positioning Engine:** A high-precision, hardware-agnostic software positioning engine that fuses GNSS data with inertial sensors and other sensor inputs to deliver reliable, absolute positioning. When integrated with Skylark, it forms an end-to-end, ASIL-compliant localization solution for autonomous and connected vehicles.

Test Drive Setup

Swift Navigation, in partnership with Korea Telecom, conducted a four-day drive test across 2,526 km of Korea's major road networks, spanning diverse environments, including urban areas, expressways, and tunnels such as the famous Daegwallyeong tunnel–the longest in the country.

The test vehicle was equipped with:

- A high-end reference system consisting of two GNSS antennas connected to a ground truth system.
- A test GNSS platform, comprising of an STMicroelectronics Teseo V automotive-grade dual-band GNSS receiver capable of outputting Skylark-corrected, SBAS-corrected and uncorrected positions.
- A Wheel Odometry interface and Inertial Navigation System (INS) integrated with Starling Positioning Engine's dead reckoning to enhance all three positioning methods.
- LTE connectivity from Korea Telecom to ensure real-time correction data availability.



A Note on SBAS

Satellite-Based Augmentation Systems (SBAS), such as KASS in Korea and WAAS in the United States, are regional satellite systems that provide augmentation to standard GNSS by leveraging a network of ground-based reference stations to monitor satellite signals for errors. Corrections are computed at a central facility and then broadcast to SBAS-enabled receivers via geostationary satellites, facilitating wide-area coverage.

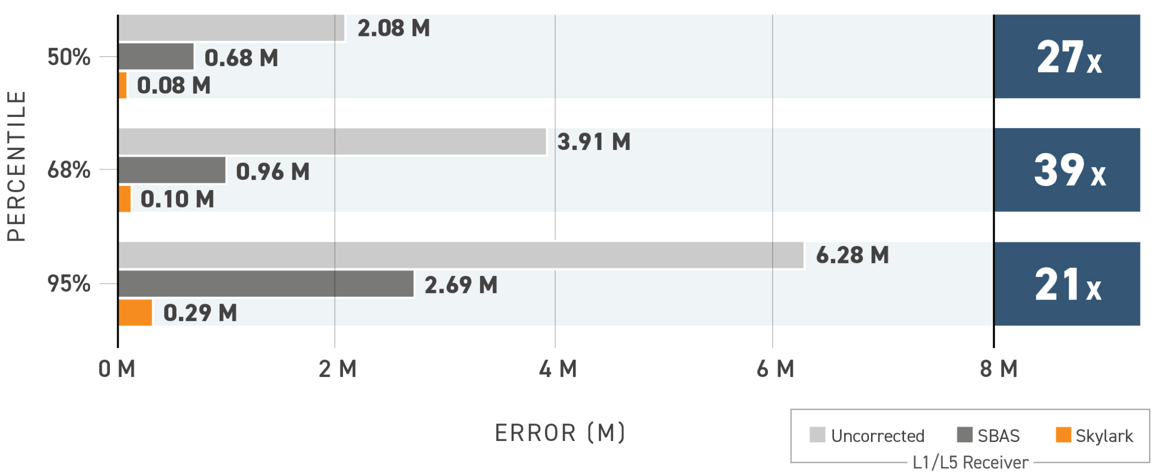
SBAS was designed to support aircraft GNSS positioning, with much higher error tolerance and unhindered skyview. SBAS corrections are much more coarse than PPP-RTK corrections, as they are designed to apply over large geographic regions rather than being tailored to localized environments, and typically offer an accuracy within 1 to 3 meters. Receiving SBAS corrections also requires line of sight with geostationary satellites, which may be low above the horizon in northern or southern latitudes. This can limit the effectiveness of SBAS in environments where obstacles such as buildings, trees, or rugged terrain obstruct the signal.

As such, SBAS is limited in its ability to meet the stringent demands of advanced driver assistance systems (ADAS), autonomous driving, and lane-level positioning. We included SBAS in our analysis because it is widely supported by GNSS receivers and freely available, making it a common baseline for comparison.

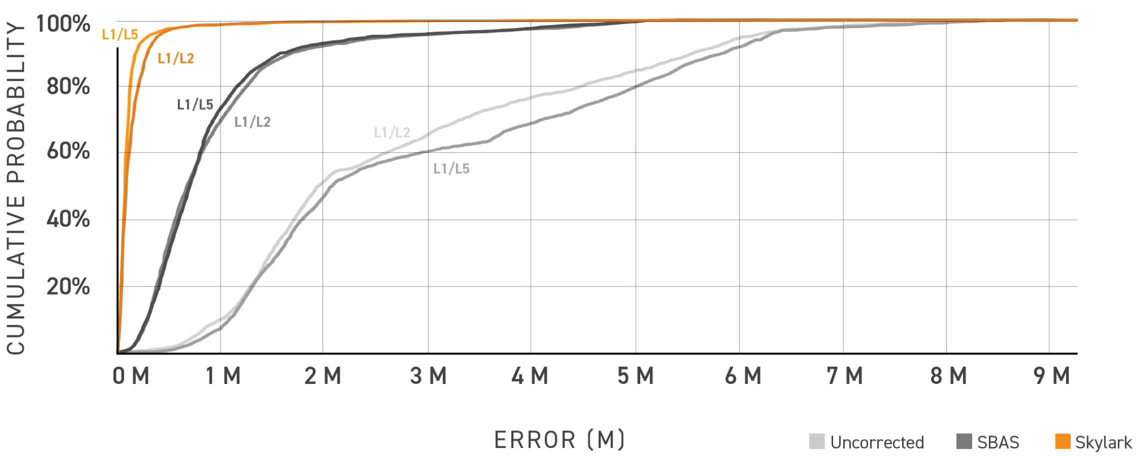
Key Takeaways

- **Nationwide Performance:** Skylark improved 95th percentile accuracy from 6.28 m to 29 cm across Korea's varied road environments—delivering up to **21x improvement** over uncorrected GNSS throughout the full drive.
- **Urban Reliability & Tunnel Continuity:** In dense urban areas and tunnels, Skylark delivered **16 cm accuracy**, enabling seamless handoff to Starling's dead reckoning and maintaining precision through GNSS outages, with RTK reacquired in just 8 seconds.
- **Lane-Level Accuracy in Complex Scenarios:** In multi-lane roads, toll gates, and highway exits, Skylark achieved **11-13 cm accuracy**, ensuring correct lane detection, safe maneuvers, and reliable automated tolling.

Full Drive Accuracy



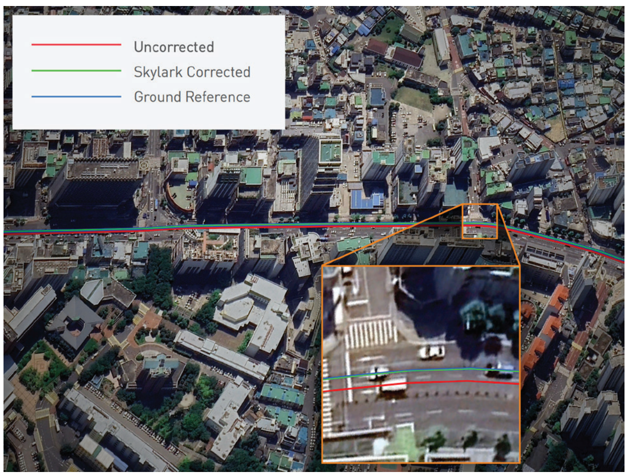
Cumulative Distribution Function



In the rest of the paper, we focus on GNSS-constrained environments where traditional GNSS solutions often become unreliable, and precision-critical scenarios where even minor positioning errors can impact safety. Skylark performance on the L1/L5 dual-frequency configuration was approximately 30% better than L1/L2, and thus only L1/L5 results are presented in subsequent analysis.

Highlighted Environments:

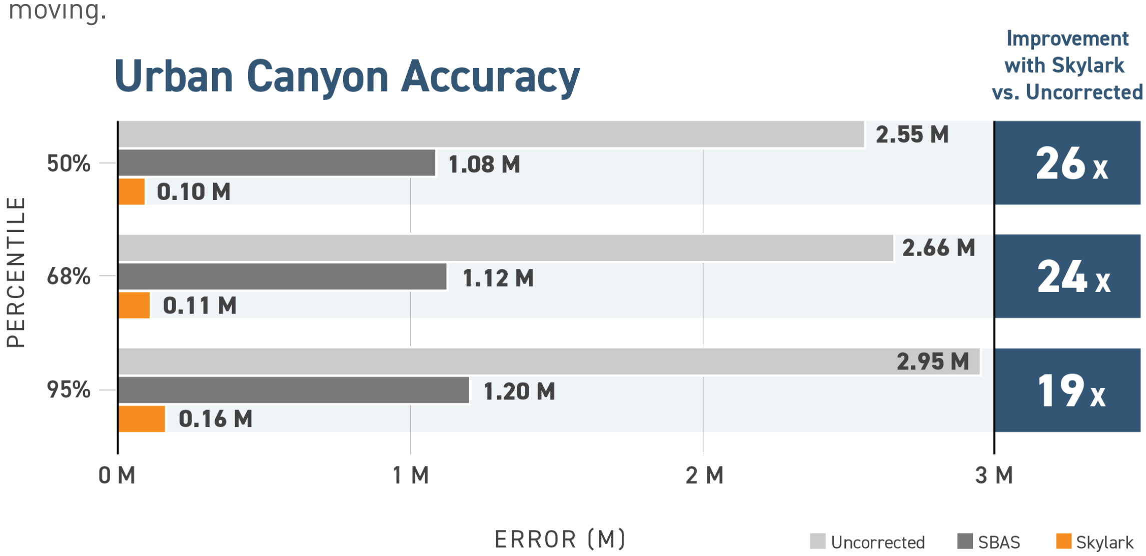
Urban Canyons



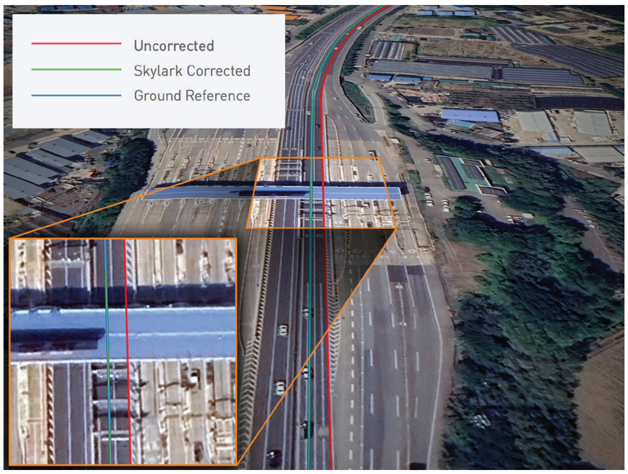
Standard GNSS in the wrong lane

Urban areas in Korea present significant challenges for GNSS-based positioning due to high-rise buildings, stacked highways, and dense infrastructure, which cause multipath errors, signal reflection and blockage. Multipath occurs when satellite signals reflect off nearby surfaces—such as buildings or vehicles—before reaching the receiver, leading to signal delays, sudden position jumps, and inaccurate location data. In urban canyons, where streets are flanked by high-rises, this effect is particularly severe, often creating large positioning errors and making navigation unreliable.

By ingesting Skylark corrections, accuracy improved 19x at the 95th percentile, from over 2.9 meters to just 16 cm, ensuring precise and stable navigation even in the most challenging city landscapes. When combined with a sensor fusion-enabled positioning engine, such as Starling, Skylark eliminates sudden position jumps, allowing ADAS applications to function with unparalleled reliability from the moment the vehicle starts moving.



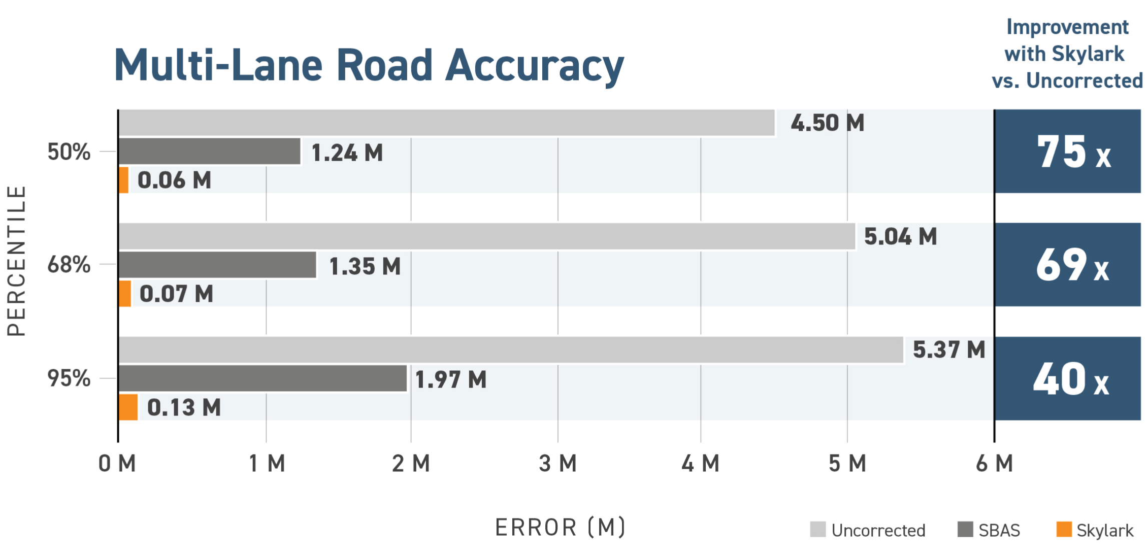
Multi-Lane Roads



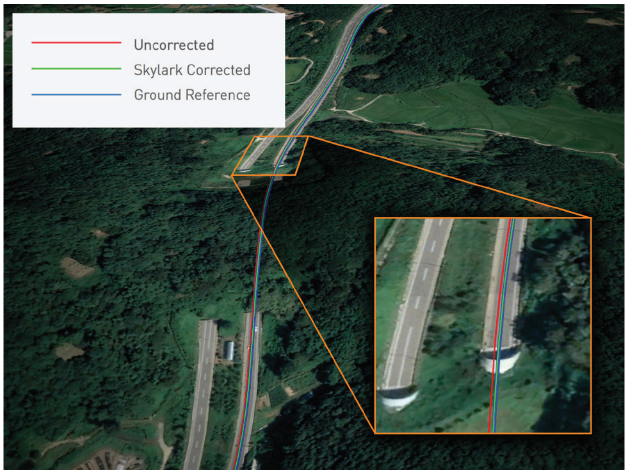
Standard GNSS in the wrong toll gate

Accurate positioning on highways and at complex intersections is critical for ADAS and autonomous systems, where even small errors can lead to incorrect lane identification and navigation failures. For Level 2+ ADAS applications, high-precision lane positioning is especially essential in urban and suburban environments. Features such as red light violation warnings depend on the vehicle's ability to match its exact lane position to traffic signal data. With Skylark, accuracy is enhanced 40x—from 5.4 meters to 13 cm—enabling advanced safety features and seamless navigation in complex road environments. Even after passing through toll booths, where GNSS signals are often temporarily lost, Skylark re-establishes an RTK fix in just 5 seconds, ensuring continuous high-accuracy positioning for autonomous and ADAS-equipped vehicles.

In South Korea, where highways have a dense network of toll booths, lane-level accuracy is also crucial for automated tolling systems. Global fleet operators lose millions annually due to tolling errors and fuel fraud caused by imprecise positioning. Skylark ensures vehicles are correctly identified at toll booths, eliminating mischarges and enabling frictionless automated payments, making tolling more efficient for both operators and drivers.



Tunnels

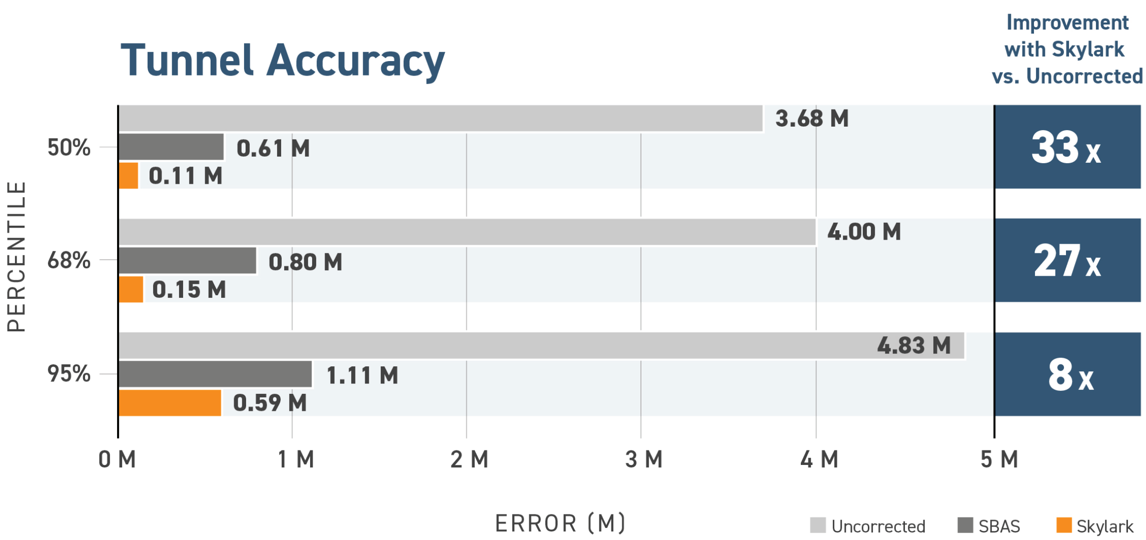


Accurate Skylark position at beginning of tunnel carried throughout

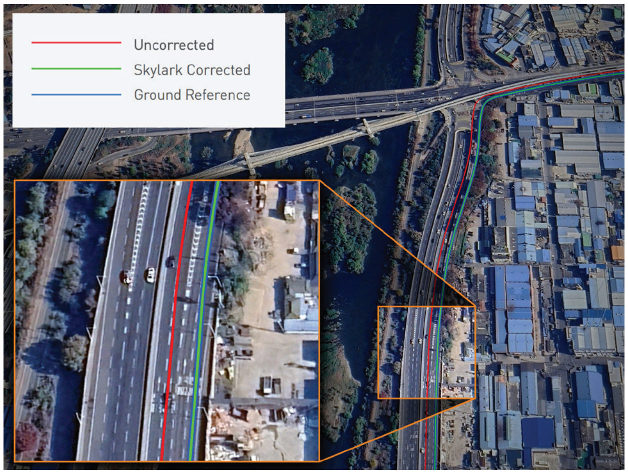
Approximately 65% of the Korean peninsula is mountainous. This terrain has resulted in there being over 1500 registered road tunnels, some of which exceed 2 km in length. Consequently, the drive test encountered instances of complete GNSS signal loss in these subterranean passages, requiring dead reckoning to maintain positioning. Dead reckoning is a navigation method that estimates a device's current position by applying velocity and bearing information, acquired from relative sensors such as wheel odometry and INS, to the vehicle's last known position.

Due to the shared test architecture, all three positioning solutions benefited from dead reckoning to sustain position through signal outages. The benefit of Skylark in this GNSS-denied environment was that it delivered a precise RTK fix to the positioning engine just before tunnel entry, enabling dead reckoning to maintain a highly accurate trajectory through the entirety of the tunnel.

Starling displayed short re-convergence time upon exiting tunnels, transitioning from dead reckoning to an RTK fix in just 8 seconds. Skylark drastically improved accuracy in this GNSS constrained environment from 4.83 meters to 59 cm at the 95th percentile.



Highway Exits

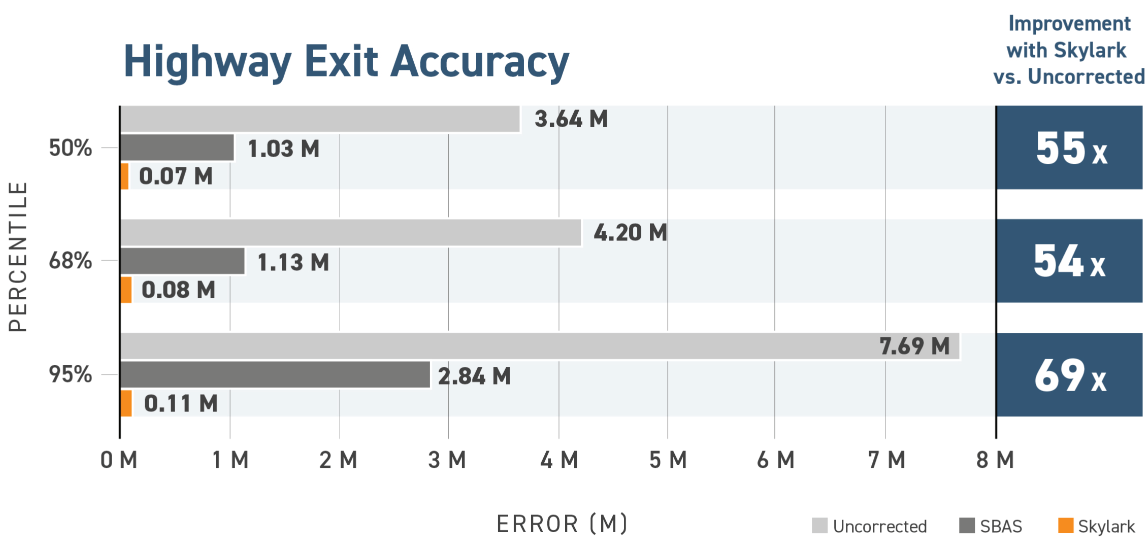


Standard GNSS missed highway exit

Precise positioning is critical at highway exits, where vehicles must accurately distinguish between adjacent lanes and determine whether they've committed to an off-ramp or continued on the main carriageway. Even minor errors in localization can result in incorrect lane identification, missed turns, or unsafe maneuvers, making high-integrity GNSS performance essential for safe navigation in these complex scenarios.

Skylark enhances accuracy from 7.69 meters to just 11 centimeters at the 95th percentile, a 69x improvement.

This level of accuracy ensures vehicles stay in the correct lane and execute safe, timely maneuvers, while also enabling smoother transitions, earlier decision-making, and more effective coordination with ADAS features and path planning algorithms.



Conclusion

The extensive drive test conducted together by Korea Telecom and Swift Navigation demonstrated the performance of Skylark™ Precise Positioning Service in real-world environments across 2,526 km throughout South Korea. Whether navigating dense urban areas, tunnels, complex highways, or mountainous terrain, Skylark consistently outperformed SBAS and traditional GNSS, achieving reliable centimeter level accuracy.

Accurate, reliable, and safe GNSS is an essential component of consumer autonomous vehicle deployments. Swift's technology is already on the road today and is trusted by 20+ automotive OEMS and Tier 1 suppliers to power 10M+ vehicles to operate with confidence. As demand grows for high-integrity positioning to support autonomy, safety, and operational efficiency, Skylark offers a scalable, cloud-native solution that meets the region's rigorous performance standards.
Through continued collaboration with Korea Telecom and local partners, Swift Navigation is unlocking the full potential of precise positioning in Korea and beyond. For more information, visit **swiftnav.com**.